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FURTHER STUDIES IN THE MICA GROUP

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The heptaphyllite micas include two distinct systems which may be designated from their commonest types, the muscovite system and the lepidolite system. In a former study[1] of the mica group the best solution then discovered for the variations in composition in these systems involved the assumption of molecules with unequal numbers of oxygen atoms. It was stated at that time that: "The variations in tenor of oxygen are considered improbable and unsatisfactory, but, nevertheless, no better solution has been found." Further study of the problem seems to show that it is unnecessary to assume molecules with unequal numbers of oxygen atoms. The following paper is, then, an attempt to modify the writer's explanation of the constitution of the heptaphyllite micas so as to bring it more fully into harmony with the theory of atomic isomorphism. The two systems included in heptaphyllite will be discussed separately, beginning with the muscovite system.

1. THE MUSCOVITE SYSTEM

In the earlier discussion of the muscovite system it was suggested that the system has three end-member molecules, namely:

Muscovite	$H_4K_2Al_2Al_4SiSi_5O_{24}$
Protolithionite	$H_4K_2F\ddot{e}_2Al_4FeSi_5O_{22}$
"Phengite"	$H_4K_2Si_2Al_4SiSi_5O_{25}$

It is only necessary to add two "phengite" molecules to one protolithionite molecule to obtain a molecule which is more satisfactory, since it contains the correct number of oxygen atoms. The resulting molecule is $H_4K_2F\ddot{e}Al_4Si_7O_{24}$, whose relationship to the muscovite molecule may be made more obvious by writing the molecules as follows:

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[1] A. N. Winchell: *Am. Jour. Sci.*, **CCIX**, 1925, p. 415.

Muscovite	$H_4K_2AlAl_4AlSi_6O_{24}$
Phengite	$H_4K_2F\ddot{e}Al_4SiSi_6O_{24}$

This last molecule is probably a better expression of the composition of the mineral called phengite by Tschermak than the formula previously assigned to it; it should be understood that the iron in the formula is ferrous and that magnesium may proxy for it in any amount—in fact, magnesium is more abundant than ferrous iron in nearly all modern analyses of phengitic micas.

The proposition that the muscovite-phengite series varies in composition from $H_4K_2Al_6Si_6O_{24}$ to $H_4K_2(Mg,Fe)Al_4Si_7O_{24}$ implies that the points representing analyses in the triangle ABC of Figure 4 of the earlier article on the micas should all be grouped along or near a line running from B to a point at 33 1/3% from A toward C. In general, the analyses, as plotted, show 5–20% too much of the protolithionite molecule (C) to fall along this line; this is due, at least in large part, to the fact that in the computations for Figure 4 it was assumed[2] that titanium and ferric iron and manganese as well as magnesium all proxy for ferrous iron, although it was stated that "there is no evidence now available to determine the role of the minor constituents in this system," and the assumption was made only because such a condition seems to exist in biotite. Further study of muscovite indicates that this assumption was probably incorrect. In computations for the present work it has been assumed that calcium and sodium proxy for potassium, ferrous iron for magnesium, ferric iron for aluminum, and titanium for silicon.

Many more analyses have been studied for the present occasion than were employed for the first discussion of heptaphyllite; indeed 110 analyses have been computed for the muscovite system alone, including all the good (and some poor) analyses listed by Doelter, and all the new analyses of Kunitz,[3] Jakob[4] and others. It has been found that 53 of these analyses can be computed into the molecules $H_4K_2Al_6Si_6O_{24}$ and $H_4K_2(Mg,Fe)Al_4Si_7O_{24}$ with discrepancies[5] of less than 3% in alumina, less than 1% in potassa, 0% in magnesia and less than 5% total (irrespective of sign);

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[2] *Am. Jour. Sci.*, **CCIX**, 1925, p. 421.

[3] *N. Jahrb. Min. Beil. Bd.*, **L.** 1924, p. 365.

[4] *Zeit. Kryst.*, **LXII**, 1925, p. 443.

[5] Discrepancies in fluorine and water are disregarded; Ca is calculated as Na, MnO as FeO and Mn_2O_3 as Al_2O_3.

these 53 analyses are plotted in Fig. 1; 24 other analyses[6] correspond with these formulas except for abnormal tenor of alkalies. Most of the other analyses are old and very probably inaccurate. It is worth noting that 16 out of the 20 recent analyses of Kunitz and Jakob correspond well with the formulas here proposed and the 4 others are abnormal only in their tenor of alkali.

Penfield's[7] "alurgite" (No. 128 of Fig. 1) is apparently even more siliceous than typical phengite. That is, phengite is produced when one MgSi group proxies for one AlAl group of the muscovite molecule. In alurgite, and also in analysis 104, this replacement is carried to completion and about twenty percent of a second AlAl group is replaced by MgSi. Therefore the points which represent the composition of these micas are a short distance outside of the triangle of Fig. 1, as suggested by the arrows.

Of course, every change of composition produces some effect upon the optic properties; since there are many minor variations in composition in the muscovite system, such as, a variable tenor of Na which proxies for K, and of Ti which proxies for Si, and of Mn and still other elements, it is impossible to prepare a diagram which will express accurately the relations between variations in composition and variations in optic properties, because no diagram can show the effects of so many variables. However, study of the data shows that, as usual, iron is especially important in its effects on the optic properties and the effects of ferrous and ferric iron are quite different. The chief effect of ferric iron is to raise the index of refraction and apparently also the birefringence, while the chief effect of ferrous iron is, like that of magnesium, to decrease the optic angle. Apparently ferrous iron has a greater effect than magnesium on the optic angle. The diagram (Fig. 1) is based on available data and represents phengite with a little ferrous iron. It may be estimated that iron-free phengite would have the optic plane normal to (010), as in muscovite, with $2V = 25° \pm$, $N_m = 1.59 \pm$, and $N_g - N_p = 0.04 \pm$, while pure iron (magnesium-free) phengite would have the optic plane parallel with (010), $2V = 10°$

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[6] These are Doelter's Nos. 9, 20, 22, 33, 36, 38, 46, 59, 61, 62, 71, 76, 78, 79, 102, 110, 113, 119, and my No. 126 (P. P. Pilipenko: *Min. Abst.*, **II**, 1923, p. 112), 127 (E. V. Shannon: *U.S. Nat. Mus. Bull.* **131**, 1926, p. 372), 135 (W. Kunitz: *loc. cit.*, No. 5), and 152, 154, 156 (J. Jakob: *Zeit. Kryst.*, **LXII**, 1925, p. 443, Nos. 2, 4, and 6).

[7] *Am. Jour. Sci.*, **CXLVI**, 1893, p. 288; Larsen (*U. S. Geol. Surv. Bull.* **679**) gives for alurgite $(-)2V =$ near 0°, $\rho > \nu$ weak, $N_m = 1.594$, $N_g - N_p =$ like muscovite.

or more, and N_m = about 1.61. It should be understood that Fig. 1 is not supposed to be highly accurate so far as the relations between composition and optic properties are concerned, but it represents an average picture of existing data. It does not express accurately the optic data of Jakob, but these seem to be decidedly less accurate than the optic data of Kunitz.

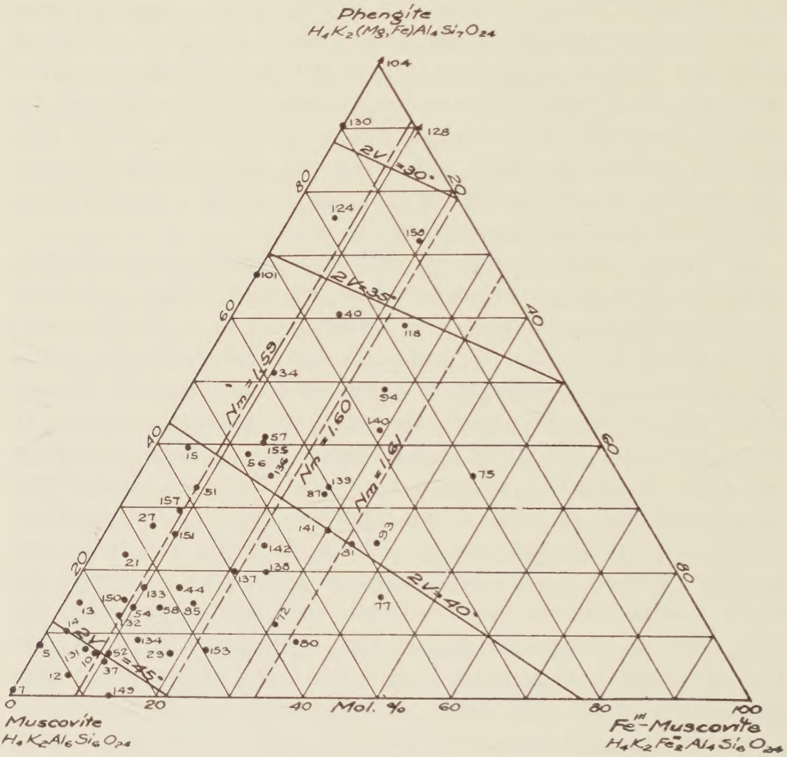

FIG. 1.

REFERENCES FOR FIG. 1.

For the chemical analyses, all numbers below 124 refer to the same numbers as listed by Doelter (HANDB. MINERALCH., **II**, 2, 1917, pp. 418–431). 124, H. Sigg: *Zeit. Kryst.*, **LVII**, 1923, p. 418. 127, E. V. Shannon: *U. S. Nat. Mus. Bull.* **131**, 1926, p. 372. 128, S. L. Penfield: *Am. Jour. Sci.*, **CXLVI**, 1893, p. 288. 130. W. Kunitz: *N. Jahrb. Min. Beil. Bd.*, **L**, 1924, p. 365. 131–142, W. Kunitz: *N. Jahrb. Min. Beil. Bd.*, **L**, 1924, p. 412, Nos. 1–12 in order. 149–158, J. Jakob: *Zeit. Kryst.*, **LXII**, 1925, p. 443, Nos. 9–18 in order. For the optic data: No. 10, R. Scharizer: *Zeit. Kryst.*, **XIII**, 1888, p. 463, gives 2E = 73° 52′ Na for muscovite from Auburn, Me. 13, A. Hutchinson and W. C. Smith: *Mineral Mag.*, **XVI**, 1912, p. 264, give

$2E=68° 50'$, $N_g=1.594$, $N_m=1.589$. 14, R. Scharizer: *Zeit. Kryst.*, **XIII**, 1888, p. 463 gives $2E=73° 52'$. 21, G. Tschermak: *Zeit. Kryst.*, **III**, 1879, p. 127, gives $2E=68° 24'$ Na. 52, R. Scharizer: *Zeit. Kryst.*, **XIII**, 1888, p. 460, gives $2E=70° 58'$ Na. 117, G. Tschermak: *Zeit. Kryst.*, **XIII**, 1879, p. 147 gives $2E=60°12'$ Na. 118, G. Tschermak: *loc. cit.*, gives $2E=55°0'$ red. 124, H. Sigg: *Zeit. Kryst.*, **LVII**, 1923, p. 418 gives $2V=36°47'$, $N_g=1.5976$, $N_m=1.5936$, $N_p=1.5574$. 128, E. S. Larsen: *U. S. Geol. Surv. Bull.* **679**, 1921, p. 39, gives for alurgite from Piedmont $2V=$nearly 0°, $\rho>\nu$ weak, $N_m=1.594$, $N_g-N_p=$like muscovite. For optic data on 130–141 see W. Kunitz: *N. Jahrb. Min. Beil. Bd.*, **L**, 1924, p. 365. For optic data on 149–158 see J. Jakob: *Zeit. Kryst.*, **LXII**, 1925, p. 443.

Since the publication of the first article[8] on the constitution and optic properties of the micas, Hallimond[9] has published an interesting discussion of the micas in which he emphasizes two points, namely, the idea that RO can replace R_2O_3 and the constancy of the $K_2O:SiO_2$ ratio. The writer believes that the $RO:R_2O_3$ ratio is variable and that K_2O is (nearly) constant, but he can not agree with Hallimond's interpretation of either of these facts. The writer believes that the $RO:R_2O_3$ ratio varies because Al_2O_3 replaces $MgSiO_3$ and *vice versa*. He believes that potash is constant (apparently with some unexplained exceptions), but does not believe that silica is constant; therefore the $K_2O:SiO_2$ ratio is not constant.

Hallimond[10] rejects the writer's view that the $K_2O:SiO_2$ ratio varies from 1:6 in muscovite and phlogopite to 1:5 in protolithionite and siderophyllite and to 1:8 in "phengite."[11] The evidence offered by him to prove that the $K_2O:SiO_2$ ratio is always 1:6 does not seem conclusive; it consists of three diagrams showing the relative abundance of all sorts of ratios of K_2O to SiO_2 in "muscovite," "lithia micas" and "biotite." Hallimond's own diagram shows that the $(K_2O:SiO_2=)1:7$ ratio is nearly as common in "muscovite" as the 1:6 ratio. However, the frequency of occurrence of various ratios is not the question at issue. It seems strange that it should be necessary to point out that it is not safe to conclude that the more uncommon ratios are all due to errors and do not actually occur. If such an assumption were correct it would be possible to prove by the same sort of method that marialite is not a mineral, but only a figment of the imagination, because it is quite rare, and the common ratio between

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[8] *Amer. Jour. Sci.*, **CCIX**, 1925, p. 309 and 415.

[9] A. F. Hallimond: *Mineral Mag.*, **XX**, 1925, p. 305, and **XXI**, 1926, p. 25.

[10] *Mineral. Mag.*, **XXI**, 1926, p. 26.

[11] This ratio is 1:7 in phengite as defined previously in this article.

Na_2O and SiO_2 in scapolite is far less than that found in marialite. Many other minerals could be proved to be non-existant by the same method.

It is not difficult to test the question at issue. So far as known to the writer no one has suggested that in muscovite proper the $K_2O:SiO_2$ is not 1:6. Consequently data in regard to muscovite proper have no bearing on the question. It has long been recognized that there is a gradation from muscovite proper to a very similar substance, called phengite by Tschermak, which is distinguished from muscovite by its small optic angle and by its high tenor of silica. The writer has suggested that in phengite the $K_2O:SiO_2$ is not 1:6. Doelter gives twenty-one analyses which he classifies as phengite. Testing these analyses by Hallimond's method of computing the number of K_2O+Na_2O molecules in each when the SiO_2+TiO_2 molecules are calculated to be 600, the following list may be obtained, taking Doelter's analyses 102–122 in regular order: assuming $SiO_2+TiO_2=600$, $K_2O+Na_2O+Ca_2O_2$[12] = 74, 86, 73, 56, 75, 45, 55, 80, 58, 79, 85, 74, 40, 37, 92, 85, 83, 68, 74, 66, 63. It is unfortunately true that all of these analyses are old and most of them probably inaccurate, but it is interesting that no one of them shows as high a tenor of alkalies as required by Hallimond's theory, the average being only 69, instead of 100. The only modern analysis of a uniaxial "muscovite," that is, a phengite, known to the writer is that published in 1924 by Kunitz;[13] this analysis contains 83 molecules of K_2O+Na_2O (and no lime) to 600 molecules of SiO_2+TiO_2. On the basis of the theory suggested by the writer this mineral should have 87 molecules[14] of alkali to 600 of SiO_2+TiO_2. Jakob[15] published in 1925 an analysis of a potash mica with a small optic angle ($2V=29°20'$); this analysis contains 83 molecules of alkali (and no lime) to 600 molecules of SiO_2+TiO_2; the theory of the writer would require 86 molecules of alkali. Penfield's "alurgite" is apparently a phengite; it contains 84 molecules of alkali (and no lime) to 600 of SiO_2+TiO_2; the writer's theory would require 83 molecules of alkali.

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[12] The writer believes that Ca proxies for K in mica as in feldspar; if Ca were omitted, according to the practice of Hallimond, the results would be slightly more unfavorable to his theory.

[13] *N. Jahrb. Min. Beil. Bd.*, **L**, 1924, p. 383.

[14] Calculated on the assumption that the iron oxide (5.92%) reported by Kunitz is all FeO.

[15] *Zeit. Krist.*, **LXII**, 1925, p. 443, No. 18.

In summary, every analysis of phengite on record shows that the mineral does not contain 100 molecules of alkali (plus lime) to 600 molecules of SiO_2+TiO_2; the old analyses give an average of only 69 molecules of alkali; the actual number present is probably greater as indicated by recent accurate analyses on carefully purified material. The data from the latest analyses accord well with the theory that the phengite molecule contains alkali in the ratio $K_2O:SiO_2=1:7$.

THE LEPIDOLITE SYSTEM

Another attempt to solve the problems of the constitution of the lepidolite system has given results which are not entirely satisfactory. However, a study of the 53 available analyses (with special attention to the best ones) seems to establish a difference between the muscovite system and the lepidolite system in the number of oxygen (plus fluorine) atoms in the unit cell or crystule. All formulas of the muscovite system contain twenty-four atoms of oxygen to two of potassium. The number of oxygen atoms in the formulas of the lepidolite system is clearly less than twenty-four; it is probably twenty-two, although twenty-one is not excluded by the data. Muscovite and lepidolite do not seem to be miscible to any important extent, and this condition is perhaps due to the different number of oxygen atoms.

If the number of oxygen atoms be disregarded (as was done in the previous study) it is reasonable to regard the muscovite molecule as one end member of the lepidolite system. Since the muscovite molecule is not satisfactory in the number of its oxygen atoms a different molecule should take its place as an end member of the lepidolite system. Hallimond[16] gives $H_4K_2Li_2Al_4Si_6O_{22}$ as the formula of lepidolite; this is exactly the composition expressed by a point in figures 4 and 5 of the writer's[17] earlier discussion of the micas at one third the distance from B toward E; it may be accepted as probably correct, at least for one kind of lepidolite. This formula has the same number of oxygen atoms and the same number of other atoms as the writer's formula for protolithionite, namely, $H_4K_2Fe_3Al_4Si_5O_{22}$, which seems to be correct for another end member of the lepidolite system.

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[16] *Mineral. Mag.*, **XX**, 1925, p. 305.

[17] *Am. Jour. Sci.*, **CCIX**, 1925, p. 415.

The correct formulas of the other end members of the lepidolite system are quite doubtful. Only two analyses of polylithionite are on record and they are old and of very questionable accuracy. Hallimond has suggested the formula $K_2O \cdot 2Li_2O \cdot Al_2O_3 \cdot 6SiO_2 \cdot 2H_2O$, which is exactly the composition expressed by a point in figures 4 and 5 of the writer's earlier article on the micas at two thirds the distance from B toward E. This formula is deficient in oxygen atoms; data at present available are quite insufficient to determine whether the formula should be written with 4 H_2O (including fluorine) or in some other way (such as with more silica) to provide the lacking oxygen atoms. For the present occasion the writer has used the formula $H_8K_2Li_4Al_2Si_6O_{22}$.

The fourth end member of the lepidolite system seems to be approximately represented in the rare mineral called cryophyllite, of which only a few old analyses are available. The formula of this mineral is given by Hallimond as follows: $H_4K_2Li_2FeAl_2Si_6O_{20}$; the data in this case indicate rather clearly that this should be written $H_4K_2Li_2FeAl_2Si_7O_{22}$; the evidence on this point will be given later.

In summary, the end members of the lepidolite system seem to be the following molecules:

Lepidolite	$H_4K_2Li_2Al_4Si_6O_{22}$
Polylithionite	$H_8K_2Li_4Al_2Si_6O_{22}$
Protolithionite	$H_4K_2Fe_3Al_4Si_5O_{22}$
Cryophyllite	$H_4K_2Li_2FeAl_2Si_7O_{22}$

The way in which atoms proxy for one another can be made more evident by writing the formulas as follows:

Lepidolite	$H_4K_2Li_2AlAl_2AlSiSi_5O_{22}$
Polylithionite	$H_8K_2Li_2LiAl_2LiSiSi_5O_{22}$
Protolithionite	$H_4K_2Fe_2FeAl_2AlAlSi_5O_{22}$
Cryophyllite	$H_4K_2Li_2FeAl_2SiSiSi_5O_{22}$

Ordinary lepidolite contains 50 to 100 per cent of the first molecule, the remainder being chiefly polylithionite with or without minor amounts of protolithionite or cryophyllite.

Ordinary lepidolite is miscible in all proportions with protolithionite and these intermediate types are known as zinnwaldite (the name lithionite has been used occasionally for some of these). The end member (protolithionite) is rather rich in iron (or magnesium) so that it is usually dark colored or black and has been called biotite probably in some cases. Polylithionite is of doubtful stability, but mica of approximately this composition has been described from Greenland. Cryophyllite is also somewhat doubtful, but has been described from Cape Ann, Massachusetts; it seems to be fairly common as a minor constituent in the lepidolite system, but almost unknown as a dominant constituent.

The chief constituents of the lepidolite system are shown in figure 2. Analyses represented by points contain no cryophyllite; the size of small triangles (or lines along the left hand edge) is proportional to the tenor of cryophyllite in the sample. Six analyses are too rich in cryophyllite to be useful in the figure; ten analyses are rather clearly inferior; thirty-three of the remaining thirty-seven are shown in Fig. 2. Many of the analyses and some of the optic data are not very accurate and analyzed samples with recorded optic data are not numerous; therefore the lines representing the relations between optic data and composition are not supposed to be very accurate; however, making a suitable allowance for the influence of cryophyllite in some cases, they give the index within about ±0.01, the optic angle within about ±5°, and the birefringence within about ±.005 in all cases carefully determined, except for Nos. 3, 10, and 22.[18] The diagram would require that polylithionite have its optic plane normal to the position found in lepidolite and zinnwaldite, that is, parallel to (010) and this is the position reported by Lorenzen;[19] his statement of the dispersion, namely $\rho<\nu$, is the reverse of that found in lepidolite and zinnwaldite, as it should be if the optic angle varies through zero as the composition varies from lepidolite to polylithionite.

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[18] As noted in the first discussion of the micas (*op. cit.* p. 418) two of these are probably incorrect; the third was reported in 1874.

[19] *Zeit. Kryst.*, IX, 1884, p. 252.

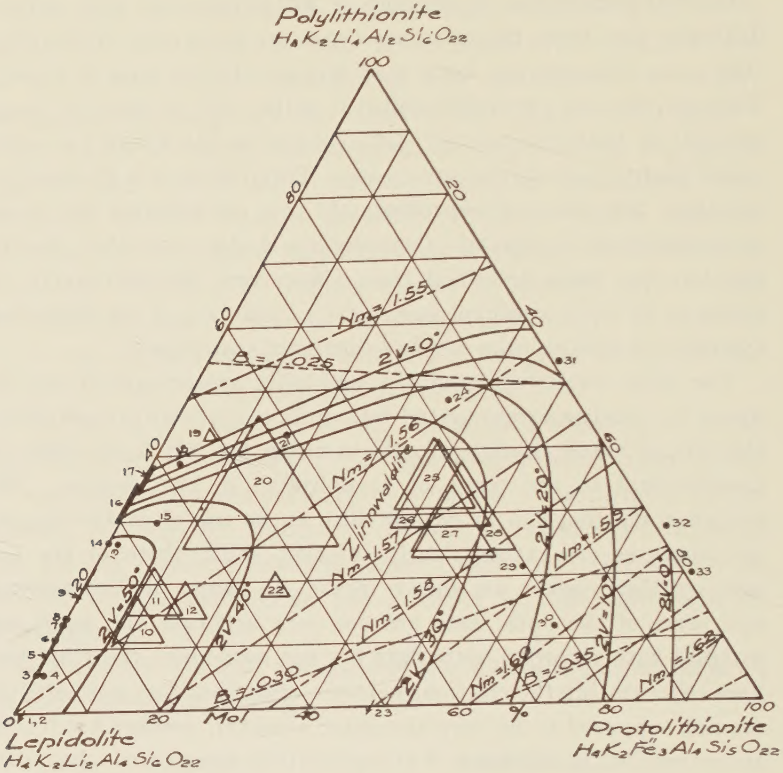

FIG. 2.

REFERENCES FOR FIG. 2.

1, 2, 3, 4, R. B. Riggs: *U. S. G. S. Bull.* 42, 1887, p. 18 (white and brown), p. 14 and p. 17, No. II. 5, 6, W. T. Schaller: *U. S. G. S. Bull.* 419, 1910, No. K and L. 7, F. Berwerth: *Min. Mit. Beil. J. R. A.*, 1877, p. 343. 8, W. T. Schaller: *U. S. G. S. Bull.* 419, 1910, p. 287, No. 1. 9, R. B. Riggs: *op. cit.* p. 17, No. I. 10, W. Kunitz: *N. Jahrb. Min. Beil. Bd.*, **L**, 1924, p. 394, 395, No. 4. 11, W. Kunitz.: *op. cit.*, p. 413, No. 2. 12, V. Dürrfeld: *Zeit. Kryst.*, **XLVI**, 1909, p. 573. 13, C. Doelter: *Min. Chem.*, **II**, 2, 1917, p. 450, No. 11. 14, W. T. Schaller: *op. cit.*, p. 287, No. H. 15, R. Scharizer: *Zeit. Kryst.*, **XII**, 1887, p. 1 and **XIII**, 1888, p. 467. 16, W. Kunitz; *op. cit.*, p. 394, 395, No. 3. 17, R. B. Riggs; *op. cit.*, p. 12. No. I. 18, A. N. Winchell: *Am. Jour. Sci.*, **CCIX**, 1925, p. 424, No. 51. 19, A. N. Winchell; *op. cit.*, No. 21a. 20, W. Kunitz; *op. cit.*, p. 394, 395, No. 5. 21, R. A. Johnston: *Am. Jour. Sci.*, **XI**, 1901, p. 149. 22, W. T. Schaller: *Am. Jour. Sci.*, **XXII**, 1907, p. 158. 23, E. S. Simpson: *Geol. Surv. W. Australia, Bull.* 48, 1915, p. 95, and A. N. Winchell; *Am. Jour. Sci.*, **CCIX**, 1925, p. 426, No. 31. 24, C. F. Rammelsberg;

Min. Chem. Sup., **1895**, p. 418. 25, Duparc, Wunder et Sabot: *Mem. Soc. Phys. Hist. Nat. Geneve*, **XXXVI**, 1910, p. 369. 26, W. Kunitz: *op.cit.*, p. 394, 395, No. 8. 27, F. Berwerth: *op. cit.*, p. 343. 28, W. Kunitz: *op. cit.*, p. 394, 395, No. 9. 29, W. Kunitz: *op. cit.*, p. 394, 395, No. 10. 30, S. Haughton: *Min. Cornwall*, **1876**, p. 72, quoted by E. S. Simpson: *Geol. Surv. W. Australia Bull.* 48, 1912, p. 95. 31, Stein: *Jour. prak. Chem.*, **XXVIII**, 1883, p. 295. 32, H. Schulze: *Zeit. prak. Geol.*, **1896**, p. 377. 33, W. Kunitz: *op. cit.*, p. 394, 395, No. 9.

Hallimond[20] has recently discussed the composition of the micas and reached the conclusion that the $K_2O:SiO_2$ ratio has the constant value 1:6 in all of them. In support of this conclusion he presents diagrams showing that this ratio is commoner than any other in "muscovite," "lithia micas" and "biotite." According to this theory such molecules as suggested above for protolithionite and cryophyllite are impossible. It is therefore necessary to examine the available data bearing on this question as applied to protolithionite and cryophyllite.

Hallimond gives a list of eleven analyses of "lepidolite-protolithionite (zinnwaldite)." One of these (Dana No. 8) is evidently included by mistake since the analysis cited does not correspond even approximately with the ratios given by Hallimond; four others are too old to be worthy of serious consideration. The six remaining analyses give the following results (assuming $SiO_2+TiO_2=600$):

		$K_2O+Na_2O+Ca_2O_2$		
ANALYST	DATE	Hallimond's theory	Found	Winchell's theory
Schaller	1907	100.	98.5	104.5
Dürrfeld	1909	100.	107.4	105.9
Kunitz 8	1924	100.	99.7	105.6
Kunitz 9	1924	100.	93.9	106.4
Kunitz 10	1924	100.	106.0	111.5
Kunitz 11	1924	100.	108.5	116.0

Three of these analyses are favorable to Hallimond's theory as compared with the writer's theory; two of them are as good for one theory as the other and one of them is favorable to the writer's theory. The differences in all cases are rather small; it is easy to demonstrate that modern analyses report more alkali than old analyses; is it possible that even in modern analyses the tenor of alkali reported is actually a little too low? It seems possible, also, that Hallimond is correct in his idea that Li_2O can proxy, *in small amount*, for K_2O; if so, this might account for the discrepancies found. Finally, it seems to the writer that other ratios are as important in micas as the $K_2O:SiO_2$ ratio, and he has been unable to find any simple formula for protolithionite containing 6 SiO_2 which satisfies these other ratios as well as does the formula with 5 SiO_2—this is especially true for the analysis richest in the protolithionite molecule, namely Kunitz No. 11.

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[20] *Mineral. Mag.*, **XX**, 1925, p. 305 and **XXI**, 1926, p. 25.

In regard to the formula of cryophyllite, Hallimond gives a list of six analyses of "lepidolite-cryophyllite"; the first of the list contains only 8% of the cryophyllite molecule and therefore should not be considered in attempting to determine the formula of that mineral. The data for the remaining five analyses are as follows (assuming $SiO_2+TiO_2=600$):

ANALYST	DATE	REF.		$K_2O+Na_2O+Ca_2O_2$		
				HALLIMOND'S THEORY	FOUND	WINCHELL'S THEORY
Cooke[21]	1867	Dana	3	100	94.3	93.8
Riggs	1887	Dana	4	100	89.6	96.4
Riggs	1887	Dana	5	100	89.4	96.7
Riggs	1887	Dana	6	100	84.2	96.9
Kunitz	1924	Kunitz	5	100	97.0	99.2

In this case the data clearly favor the theory of the writer as compared with that of Hallimond. It is worthy of note that K_2O is insufficient to equal the requirements of the writer's theory in every case studied, namely, phengite, protolithionite and cryophyllite. This is perhaps due to one or more of the reasons given in connection with the case of protolithionite.

Summarizing the conclusions reached in this article it may be said that although the formulas of the end-members of the lepidolite system are still in doubt, the formulas proposed in this article correspond reasonably well with the best analyses. These formulas are characterized by having a constant number of K(+Na+Ca) atoms, a constant number of O(+F) atoms, and a constant number of other atoms. (Such a constancy seems to be required in molecules which are miscible in the crystal state by our present knowledge of crystal space lattices.) The writer is unable to accept the conclusion of Hallimond that the $K_2O:SiO_2$ ratio is 1:6 in all mica molecules and gives the evidence to show that it is 1:7 in phengite and cryophyllite. He believes that the $K_2O:SiO_2$ ratio is 1:5 in protolithionite, partly because he has been unable to find any simple formula for that molecule containing 6 SiO_2 which satisfies the other ratios as well as does the formula with 5 SiO_2.

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[21] SiO_2 increased to 53.46 (as done by Riggs and Doleter) by adding SiO_2 from SiF_4 reported.

This article has benefited by the constructive criticism of Professor R. C. Emmons.

ROEMERITE FROM CALIFORNIA

Robert E. Landon, *University of California.*

Roemerite occurs as one of the interesting sulphates developed by the alteration of pyrrhotite at Island Mountain, Trinity County, California. Several very fine specimens of this rare sulphate were collected by Mr. Vonsen of Petaluma, California, and since no American locality has hitherto been given for its occurrence, it was thought worthy of note. It was mentioned as one of the interesting secondary minerals from the pyrrhotite with claudetite, bieberite, goslarite, fibroferrite, and morenosite by Dr. Eakle[1] in his bulletin, but no description of the crystals was given.

The first report of roemerite appears in 1858,[2] when it was found in the Rammelsberg mine in the Hartz mountains, near Goslar. Grailich, who was the first to describe the mineral, measured the interfacial angles with a contact goniometer, and concluded that the mineral was monoclinic in crystallization. Chemical analyses were made of the same material by Tschermak. J. Blaas[3] reported roemerite from Persia in 1885. His material came in smaller but better crystals, so that it was possible to use a reflection goniometer. The results of Blaas' work showed that the mineral was not monoclinic, but triclinic. In 1888[4] roemerite was discovered in Chile, where it occurs with several other natural sulphates. The

[1] Minerals of California, A. S. Eakle; *Bull.* **91**, *Calif. State Min. Bureau*, p. 280.

[2] Der Römerit, ein neues Mineral aus dem Rammelsberge, Joseph Grailich; *Sitzungsberichte d. k. Akadamie der Wissenschaften*, *Wien*, 28 (1858), pp. 272–288.

[3] Beiträge zur Kenntniss natürlicher wasserhaltiger Doppelsulfate, J. Blaas; *Zeitschr. für Kryst.*, **10**, (1885), pp. 409–412.

[4] Beiträge zur Kenntniss der Sulfate von Tierra ammarilla bei Copiapo in Chile, G. Linck; *Zeitschr. für Kryst.* **15** (1889), pp. 22–26.

study of these crystals confirmed Blaas' work on their crystallization.

California roemerite is cinnamon-brown or chestnut-brown in color, and occurs in stocky to tabular crystals up to 5mm. in length, and 2 or 3mm. in width and thickness. It is commonly associated with a yellowish earthy oxide like coquimbite. The (001), (100) and the (110) faces are the most prominent.

The crystal measurements show beyond a doubt that the mineral is triclinic, although the axial ratios and interaxial angles were not redetermined because of poor terminal faces. In the prism zone, which is the best developed, three new forms were found. No new terminal faces were seen. As a rule the crystals are mounted on the terminal faces, leaving a free development of the prism faces.

Three different orientations have been used in describing roemerite. Blaas used an orientation which made the cleavage parallel the brachypinacoid. Linck made the cleavage parallel the base. Goldschmidt[5] made the cleavage parallel the front pinacoid. The last two orientations differ essentially from the first, but Goldschmidt's orientation makes the domes in Linck's crystal, prisms, and vice versa. The negative end of the *c* axis becomes the positive end of the *a* axis of the other. This interchange of axes appears in the axial ratios and interaxial angles, as an interchange of the values of the former, and as interchanged supplementary angles in the latter.

Table 1. Interaxial Angles and Axial Ratios as Determined by Early Workers.

	α	β	γ	Ratios
Blaas	89° 44′	102° 17′	85° 18′	.8791:1: .8475
Linck	116° 2′	94° 41′	80° 8′	.9682:1:2.6329
Goldschmidt	99° 53′	94° 30′	63° 57′	2.6425:1: .9684

Goldschmidt lists a total of thirteen forms, three of which are pinacoids, six are prisms, two are bracydomes, and two are macrodomes. The California crystals showed three new prisms, one positive, and the other two negative. No pyramids have been reported, and none were found on the new crystals.

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[5] Goldschmidt, Victor; Krystallographische Winkeltabellen, Verlag von Julius Springer, *Berlin* (1897), p. 295.

TABLE 2. FORMS OBSERVED ON ROEMERITE

Number	Miller index	letter	ϕ angle	ρ angle
1	(001)	*c*	not read	
2	(010)	*b*	0° 00′	90° 00′
3	(100)	*a*	114° 53′	“
4	(110)	*m*	21° 15′	“
5	(210)	*n*	44° 44′	“
6	(310)	*s*	62° 42′	“
7	(18·5·0)	*t*	69° 31′	“
8	(410)	*l*	75° 50′	“
9	(1$\bar{1}$0)	*M*	164° 57′	“
10	(023)	μ	not present	
11	(0$\bar{1}$1)	*e*	present but only approximately read.	
12	(805)	*y*	“ “ “ “	“
13	($\bar{1}$01)	*x*	“ “ “ “	“
New forms 14	(120)	*f*	9° 26′	90° 00′
15 “	“ (2$\bar{1}$0)	*g*	156° 47′	“
16 “	“ (4$\bar{1}$0)	*h*	143° 5′	“

Forms 1–13 are listed from Goldschmidt, with slight modification in letters used. Forms 14–16 are new. All readings given are from measurements of California roemerite.

The optical properties of the California mineral, as determined by Mr. Charles Anderson of the University of California, are as follows: Color, yellow-brown in thick grains, colorless in thin grains; slightly pleochroic; X = reddish yellow, Y = pale yellow, Z = yellow-brown; biaxial, negative; $2V = 49° \pm 3°$ (measured). Strong dispersion, $\rho > \nu$; distinctly crossed dispersion. All grains perpendicular to X show abnormal interference tints due to dispersion; dispersion of the bisectrices marked, sharp extinction in other sections. Indices, $\alpha = 1.526$, $\beta = 1.571$, $\gamma = 1.582$, all ±.003. These determinations are essentially concordant with earlier ones made by Linck, and others.

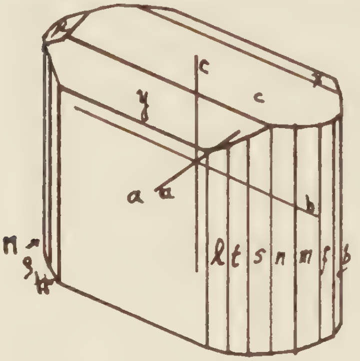

Figure 1. Roemerite crystal in normal position. Magnified 75 ×.

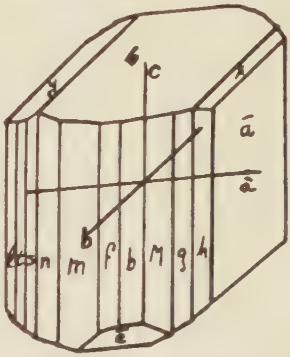

Figure 2. Roemerite crystal rotated 115° to the right of the normal position. Magnified 75 ×.

TABLE 3

Analyst	SO_3	Fe_2O_3	FeO	H_2O	Miscellaneous
Tschermak	41.54%	20.63%	6.26%	28.00	1.97% Zn; 58% Ca.
Blaas	40.95	20.50	4.12	30.82	3.59% MgO
Linck	38.47	17.62	9.06	34.10	1.02% Al_2O_3
Mackintosh[6]	40.19	19.40	9.52	30.85	0.14% Na_2O
Landon	38.30	20.60	6.94	33.40	0.0 % Cao, MgO, or Al_2O_3.

In the above table Tschermak's analysis represents the original material as given in Grailich's paper, Blaas' analysis represents roemerite from Persia, Linck's and Mackintosh's analyses of material from Chile, and the last represents roemerite from California.

Chemically, roemerite is a double sulphate of ferrous and ferric iron, the ferrous iron of which may sometimes be replaced by zinc and magnesium, and the ferric iron by aluminum. The amount of combined water may be variable.

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[6] Iron sulphates from Chile, J. B. Mackintosh; *Am. J. Sc.*, *Third Series*, **38** (1889, vol. 2), p. 243.

Although these analyses do not correspond in every detail, they nevertheless indicate a general composition which may be represented by the formula: $FeO \cdot Fe_2O_3 \cdot 4SO_3 \cdot 12$ to $15\ H_2O$. The mineral is exceptionally soluble in water, with an acid reaction. It has an astringent taste. It alters to a yellowish white ferric salt, probably coquimbite. Its high solubility, and the ease with which the mineral loses water with the simultaneous oxidation of the ferrous iron, account for its rarity.

PIEDMONTITE FROM THE SULPHUR SPRING VALLEY, ARIZONA.[1]

CARL LAUSEN, *University of Arizona.*

A specimen of piedmontite was sent to the Arizona Bureau of Mines for identification, and the locality was visited by the writer and additional material collected for study. The locality is on the southeast slope of the Pat Hills, in the Sulphur Spring Valley, southeastern Arizona. More exactly, it is near the northern edge of T.27 E., R.17 S., Gila and Salt River Base and Meridian.

The volcanic rocks in this region consist of a series of andesitic flows, dark gray in color, and with a porphyritic texture. Both hornblende and plagioclase feldspar occur as phenocrysts in a fine-grained groundmass. In a thin section of the fresh rock the hornblende is of a brownish color, strongly pleochroic, and with a small extinction angle. This is probably a variety of basaltic hornblende. Grains of magnetite are commonly associated with it, especially where the hornblende shows a resorption border. The plagioclase feldspar is present in the slide as rather stout laths which are considerably smaller in size then the crystals of hornblende, and show a more or less parallel arrangement. Polysynthetic twinning is common, and the maximum extinction angle in the symmetrical zone shows them to be basic andesine, near Ab_1An_1. The groundmass is microcrystalline, and appears to consist largely of minute feldspar laths together with scattered grains of magnetite and a little apatite. The texture is porphyritic.

As the amphibole in this rock is a variety known as basaltic hornblende, a mineral sometimes found in basalt and the more basic andesites, some petrographers would probably classify the rock as an olivine-free basalt; but the plagioclase is basic andesine, near Ab_1An_1, and the rock should be placed with the andesites.

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[1] Published by permission of the Director, Arizona Bureau of Mines.

Piedmontite occurs at this locality as narrow veinlets, usually less than one millimeter in thickness, and filling fractures in the andesite. It also occurs, to a certain extent, as single crystals, or an aggregate of crystals replacing feldspar and hornblende throughout the mass of the rock. On a fracture surface the rock is coated with a thin layer of the mineral, commonly as small rosettes of minute crystals seldom over one millimeter in length. Where the piedmontite has replaced either feldspar or hornblende, radiating clusters of the mineral are less common, and the single crystals or grains have no particular orientation. In some cases clusters have been found to occupy cavities in the rock, and the longer crystals when examined with a microscope show terminal faces, but the individual crystals are too small to be mounted and measured on the goniometer.

Associated with the piedmontite is considerable quartz and some kaolin. This silicification of the andesite appears to have accompanied the formation of the piedmontite, while the kaolin is probably the result of surface waters altering unreplaced feldspar or perhaps sericite. Cutting the andesite in all directions are numerous veinlets of calcite carrying small amounts of malachite and chrysocolla. These calcite veins with associated copper minerals are not related in origin to the piedmontite, but are much later.

At this locality the piedmontite is of a cherry-red color, and corresponds rather closely to 71″–i, in Ridgway's Color Standards and Nomenclature. However, where the individual crystals are very minute the aggregate has an earthy appearance, and is then the color of old rose. A rather unusual feature of some of the rosettes is shown in Fig. 1. Here, the central portion of the rosette is piedmontite of a dark, reddish color, and surrounding this there is a light-colored portion of a pale yellow color, and the line of demarkation between the two is rather sharp. Very likely the light-colored portion of the rosette is a variety of epidote low in iron. The red and pale yellow portions of each crystal have the same optical orientation. This would suggest that the supply of manganese suddenly ceased, and the crystal continued to grow as a variety of common epidote. An examination of crystals of piedmontite in thin sections with both upper and lower nicols out shows a greater intensity of color near the center of the crystal. This concentration of color applied both to the red and yellow tints. Occasionally the central portion of a grain is red while the border on each side is pale yellow.

The mineral is remarkably fresh and unaltered even within a few feet of the surface. On some of the fracture planes there is a thin, black film of manganese oxide; and a close examination of some of the rosettes as well as cavities in the rock show a pulverulent black substance that may be pyrolusite.

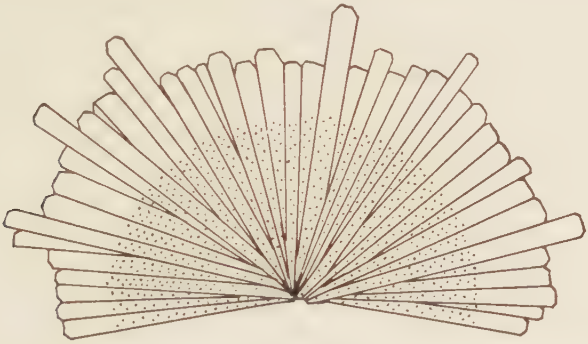

Fig. 1. Rosette of piedmontite. Center red, surrounded by light-colored variety of epidote. Enlarged drawing of a small rosette.

Piedmontite, like epidote, is monoclinic in crystallization, and is elongated parallel to the ortho-axis. The plane of the optic axes is parallel to (010); perpendicular to the basal cleavage. The mineral is optically positive. Refraction and double refraction high. Extinction $X \wedge c$ axis is $-3°30''$ (av. of several determinations). Pleochroism strong, X = amethystine red; Y = light rose; Z = deep, lemon yellow.

Chemically, piedmontite is a basic orthosilicate of calcium, aluminum, iron, and manganese, and belongs to the epidote group. The Mn_2O_3 varies from 5 to 15 per cent.[2] A determination of the manganese in the piedmontite from the Pat Hills was made by Dr. Buehrer of the Department of Chemistry, University of Arizona. He found the mineral to contain 8.91 per cent. manganese oxide calculated as Mn_2O_3. It would be interesting to know if those portions of the crystal which are of a deeper color contain a higher percentage of manganese, but the small size of the crystals makes this determination impossible.

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[2] Dana's Textbook of Mineralogy, 3rd edition by W. E. Ford: p. 532 (1922).

The piedmontite was deposited by hydrothermal solutions reacting with the silicates in the andesite, chiefly feldspar and hornblende. In addition to manganese, the solutions carried considerable silica. It is possible that these solutions as well as the manganese may have had their origin in the andesite flows, and the manganese abstracted from the ferromagnesian silicates.

OTHER OCCURRENCES OF PIEDMONTITE. At St. Marcel,[3] in the Valley of Aosta, in Piedmont, this mineral occurs in braunite, and is associated with quartz, greenovite, violan, and tremolite. It is also common in the glaucophane and chlorite schists of Japan.[4] Here, it is associated with garnet, rutile, orthoclase, and hematite in schists. A manganese epidote occurs in the crystalline limestone at Jakobsberg,[5] Nordmark, Sweden. Piedmontite from Annapolis, Missouri, was described by E. Harworth,[6] and occurs in a quartz porphyry. This mineral has also been found in the mica schists of the Island of Groix,[7] and in the Central Plateau at Haute-Loire as microscopic crystals in granulite. At South Mountain, Pennsylvania,[8] the mineral occurs in aporhyolite associated with scheelite. The mineral appears to have replaced old spherulites. Piedmontite has been found in red granite at Djebel Dokhan, Egypt.[9] Piedmontite crystals from Jothvád in Nárukat, India, have been described by Fermor.[10] Rogers[11] found piedmontite as a microscopic constituent in a thin section of quartz porphyry from a boulder in Pliocene or Pleistocene gravels at Pacific Beach, San Diego Co., California. The location of the igneous mass from which this boulder was derived is, however, unknown. The mineral appears to have replaced some ferromagnesian constituent, probably biotite. Associated with the piedmontite is common epidote and black grains of manganese oxide.

[3] Dana, E. S.; A System of Mineralogy: pp. 521–522 (1898).

[4] Koto, B.; *Jour. Coll. of Sci., Imp. Univ. Tokyo*, **1**, p. 303 (1887).

[5] Laspeyres; *Zeitsch. f. Kryst.*, **4**, p. 435 (1880).

[6] Harworth, E.; *Am. Geologist*, **1**, p. 365 (1888).

[7] Lacroix, A.; Minéralogie de la France et des ses colonies: **1**, pp. 153–155, (1893–95).

[8] Williams, G. H.; Piedmontite and scheelite from the ancient rhyolite of South Mountain, Pennsylvania: *Am. J. Sci.*, **36**, 3rd series, pp. 50–57 (1893).

[9] Liebisch, Th.; *Zeitschr. d. geol. Ges.*, **29**, 717 (1877).

[10] Fermor; *Mem. Geol. Sur. India*, **37** (1909).

[11] Rogers, A. F.; Notes on rare minerals from California: *School of Mines Quarterly*, **33**, p. 373–381 (1912).

Many of the original papers quoted above were not available to the writer, and the references were obtained in part from that excellent paper by Williams in the *American Journal of Science*, to which the reader is referred for additional information.

VOLTAITE FROM JEROME, ARIZONA

Charles A. Anderson, *University of California.*

The Department of Geological Sciences, University of California, has received some very good specimens of the rare mineral voltaite from Jerome, Arizona, sent by Mr. George L. McIntyre of Eureka, Utah. He reported that the specimens were formed in brecciated quartz immediately above burning sulphide ore on the upper levels of the United Verde Mine. It is his opinion that the voltaite has been formed by the ascending sulphur vapors. The ore of the mine has been burning for a number of years; it was first set on fire when the back of a stope collapsed and the friction ignited the sulphur present in the sulphides. Reber[1] reported the burning sulphide ore in his report on the region, but he made no mention of the voltaite. This article was prepared under the direction of Professor Arthur S. Eakle and the writer wishes to gratefully acknowledge his aid and helpful criticism.

The mineral when fresh occurs in small, black, opaque, resinous crystals varying in size from 1 mm. to 5 mm. Crystals of the 1 to 2 mm. size predominate; only in one specimen were the larger crystals obtained. The hardness is about 3 and the mineral gives a greenish gray streak. The specific gravity as determined with a Jolly balance is 2.75. The fracture is conchoidal with no apparent cleavage. It is difficultly soluble in water but goes into solution readily with dilute acid. A strong potassium flame is obtained before that blow-pipe and the assay turns to a brick-red powder.

Several of the crystals were measured on a Fuess reflecting goniometer and good reflections were obtained from the faces of the fresh crystals. The crystals are isometric with the majority showing simple cubes, but the combination of cube and octahedron was found on several crystals, and one crystal is a combination of the octahedron and dodecahedron.

Under the microscope, the voltaite is transparent, having a pale green color. The mineral is isotropic and the index of refraction determined by the oil immersion method is 1.604 ± .003. This corresponds to the optical properties of voltaite determined by Larsen.[2]

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[1] Reber: *Am. Inst. Min. Met. Eng.*, **66** (1922).

A chemical analysis was made of hand picked material. The water content was determined by the Penfield closed tube method adding lead oxide to keep the sulphur trioxide from escaping. Very satisfactory results were obtained in this manner. The ferrous iron and the total iron were determined by titration with potassium permanganate, while the ferric iron plus alumina were determined by precipitation with ammonium hydroxide. The magnesia, sulphur tri-oxide, and potassium oxide were determined by standard gravimetric methods.

The chemical analysis is as follows:

SO_3	47.83
Al_2O_3	6.06
Fe_2O_3	14.34
FeO	8.82
MgO	1.55
K_2O	4.52
H_2O	16.13
Total	99.25

The voltaite alters rather quickly upon exposure to the air, forming a yellow powder. When studied under the microscope this was found to consist of an uniaxial and a biaxial mineral. The uniaxial mineral is yellow in color with a low birefringence; it is optically positive. The indices, determined are $\epsilon = 1.538$, $\omega = 1.532$. These values are low for coquimbite, the hydrous ferric sulphate, but Larsen[3] has found a similar mineral associated with voltaite from Sierra de Caporasee, Chile, and believes it to be related to coquimbite. The biaxial mineral occurs in minute plates, distinctly pleochroic, Z = yellow green, Y = colorless. X is perpendicular to the plates and was not determined. The birefringence is strong, $\gamma = 1.602 \pm .003$, $\beta = 1.563 \pm .003$, α was not determined. $2V = 45° \pm 5°$. The mineral is optically positive. This agrees satisfactorily with Larsen's determination of the optical properties of copiapite, the platy hydrous ferric sulphate. The copiapite is by far the more plentiful of the two minerals; a rough estimate from a study of the powder in oils gave, copiapite 80%, coquimbite 20%.

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[2] Larsen: *U. S. G. S. Bull.*, **679**, p. 155 (1921).

[3] *Op. cit.*, p. 155.

Thus we have two hydrous ferric sulphate minerals forming as alteration products from the voltaite.

Voltaite was first observed in 1792 by Breislack in the solfatara near Naples, Italy, but it was not named until 1841 by Scacchi.[4] In 1867, Tschermak[5] discovered voltaite in Kremnitz, Hungary, associated with melanterite. Blass[6] made the next discovery; in 1883, he found voltaite in an altered pyritiferous trachyte from the region of Madeni Zagh, Persia. Schmölnitz, Hungary, yielded the next find of voltaite crystals; Krenner[7] described these in 1887. Collins[8] was the next to describe a new locality of voltaite; he found octahedrons of voltaite associate with coquimbite and melanterite in a filled cavity close to the cap of an orebody in Concepcion Mine, Spain. Larsen[9] used voltaite from Sierra de Caporasse, Chile, for the determination of the optical properties; he obtained it from Colonel Roebling's collection but no mention is made of the date of its discovery. Thus, the voltaite from Arizona seems to be the seventh reported locality of this mineral. Ablich[10] made artificial voltaite crystals in 1842 by allowing the constituents to evaporate in a sulphuric acid solution at room temperature.

The outstanding difference between the voltaite from Jerome, Arizona, and voltaite from other localities is the low percentage of RO and comparatively high percentage of R_2O_3. However, $RO+R_2O_3$ is approximately equal in all cases. It is interesting to note however that the artificial voltaite made by Ablich has the same characteristics regarding the ratios of RO and R_2O_3.

The presence of the voltaite only in the upper levels of the United Verde Mine immediately above the burning sulphide ore indicates that it is connected genetically with this phenomenon. The high percentage of water is rather suggestive that the voltaite was deposited from aqueous solutions at comparatively low temperatures. Scacchi[11] believes that the voltaite at the solfatara near Naples was formed by the ascending sulphur gases uniting with the decomposed rocks of the solfatara. At Jerome, the hanging wall of the mineralized area is diorite, but the voltaite is not formed by direct contact with the diorite as shown by its occurrence in brecciated quartz, but it might well have formed by a concentration of the sulphur vapors in the ground waters above, which would probably contain iron, magnesia, and potash as a result of decomposition of the diorite. This would be more or less comparable to the conditions in the solfatara where the voltaite was first found.

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[4] Scacchi: *Zeit. d. Geol. Ges.*, 4, 163 (1852).

[5] Tschermak: *Sitzungsber. d. Akad. Wien.*, **56**, (1) 831 (1867).

[6] Blaas: *Zeitsch. f. Kryst.*, **10**, p. 409.

[7] Krenner: *Földt. Közl.*, **17**, 556 (1887).

[8] Collins: *Mineral. Mag.*, **XX**, No. 100, p. 34 (1923).

[9] *Op. cit.*

[10] Scharizer: *Zeit. f. Kryst.*, **54**, 123 (1914).

[11] Scacchi: *Op. cit.*

Some altered pyrite from Shasta County, California, was sent to the University of California and examined by the writer. A large amount of this is melanterite, but minute black octahedrons are scattered throughout the mass. Microscopic study with oils showed that these octahedrons were isotropic, $n=1.596 \pm .003$. The color under the microscope is a pale oil green; the fracture is conchoidal. The crystals were too minute for goniometric or blowpipe study, but the association with melanterite, the same association found in Kremnitz, Hungary and Concepcion Mine, Spain, plus the optical properties which correspond with those of voltaite, suggest very strongly that we have the mineral voltaite in California, making two known occurrences in North America.

AN OCCURRENCE OF PITTICITE IN NEVADA

William F. Foshag, *U. S. National Museum*[1]

AND

H. G. Clinton, *Manhattan, Nevada.*

The iron arsenate-sulphate, pitticite, was first found by one of us (H. G. C.) in 1923 on the 400 foot level of the White Caps Mine at Manhattan, Nevada, as a secondary formation in the old workings.

The White Caps ore body represents a replacement and impregnation of limestone of Cambrian age, in this district called the "White Caps Limestone." The ore minerals are the sulphides of arsenic, realgar and orpiment, the sulphide of antimony, stibnite, and minor amounts of pyrite. The ore values are entirely its gold content. The gangue minerals are calcite, in part recrystallized into large rhombs, quartz and adularia feldspar

[1] Published with the permission of the Secretary of the Smithsonian Institution.

replacing the limestone, and small amounts of sericite. Other minerals in small amounts in the deposits are fluorite, barite and cinnabar. Secondary minerals are the arsenates, haidingerite and pharmacolite, the oxides of antimony, stibiconite, valentinite and senarmontite (?), the oxysulphide kermesite, calcite, gypsum, sulphur, limonite and manganese oxides.

The pitticite forms crusts upon the limestone walls and floor of a drift, thin seams in melanterite or small globular forms upon melanterite stalactites. Its color varies from brownish red to almost black, with deep red reflections from the cracks in the mineral. The color of the small grains is kaiser brown (Ridgeway's color standard) while that of the powdered mineral is ocher brown. In appearance the mineral is typically a colloid. The surface of the crusts, when unbroken, is botryoidal and the mineral shows a perfect conchoidal fracture. It is very brittle; small fragments can easily be broken off with the finger nail. The lustre on the fracture is decidedly glassy.

Under the microscope the pitticite is light yellowish brown in color, transparent and completely isotropic. The index of refraction is only slightly variable in the specimen examined and analyzed, ranging from 1.615 to 1.617.

The pitticite is easily soluble in acids without leaving an appreciable residue. The solution gives the usual reactions for iron, sulphur and arsenic. The material selected for analysis consisted of clear grains with glassy lustre and fine conchoidal fracture. An analysis of this sample (No. 95426, U. S. National Museum Coll.) gave the following results:

Analysis of Pitticite from Manhattan, Nevada
(William F. Foshag, Analyst)

	Per cent	Molecular ratios
Insol.	0.41	
H_2O	29.64	1.6466
Al_2O_3	3.11	.0304
Fe_2O_3	34.01	.2129
FeO	0.72	
CaO	trace	
MgO	trace	
SO_3	17.97	.2246
As_2O_5	14.54	.0632
	100.40	

As one might expect from material of this character the constituents are not present in definite proportions. In the molecular ratios given above, the sulphate is considerably in excess of the arsenate and both combined are somewhat in excess of the bases. This relation is perhaps due to the presence of some occluded free sulphuric acid. The mineral may be considered as a colloidal mixture of normal arsenate of iron with colloidal sulphate of iron.

The source of the constituents of the pitticite is a thin bedded pyritiferous limestone that is somewhat darker in color than the usual White Caps limestone. The pitticite oozes out of joints, cracks and bedding planes and incrusts the surface of the limestone to a thickness of 1/8 to 1/2 inch. At one spot the pitticite bearing solutions drip from the roof forming small stalactites and form a thick crust on the floor. Between two areas of pitticite is a patch of the iron sulphate, melanterite, forming in some places long, slender, green stalactites on the roof and thick stubby stalagmites on the floor. Some stalactites are cut by thin seams of pitticite and a few were collected with small pea-shaped globules of pitticite attached to their outer surface. Below both the pitticite and the melanterite is a growth of snow white epsomite crystals, one to two inches long.

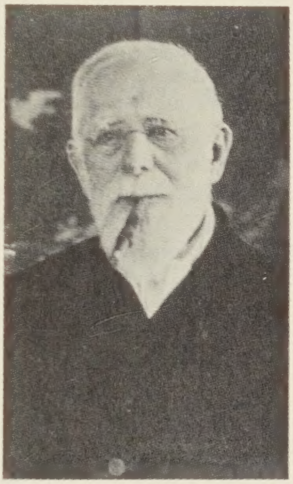
The pitticite is a recent formation having been produced since the opening of the drift. It may be well to note here that haidingerite and pharmacolite are also recent formations, being best developed on the broken rock of a small stope of low grade ore on the 900 foot level. The pitticite may be the result of the oxidation of pyrite in the limestone, the iron sulphate so generated reacting with the realgar so abundantly present in this portion of the mine. Or it may be the result of the direct oxidation of arsenopyrite, a mineral believed to be sparingly, although widely distributed in the mine.

The writers are indebted to the White Caps Company and to Mr. Walter Fancher, superintendent of the mine, for the courtesy of allowing several examinations of the mineral occurrences.

NOTES AND NEWS

Hofrat Professor Dr. Gustav Tschermak, 1836–1927

The recent death of the veteran mineralogist, Professor Gustav Tschermak, will bring sadness to the members of The Mineralogical Society of America, and to everyone interested in the science throughout the civilized world. He was ninety-one years old in April, and in the early morning of May 4th passed quietly away. A letter from Fräulein Antonia Lichtblau, who had given him the devoted care of a daughter for many years, gives the details of his last days. The picture taken about the time of his ninetieth birthday (1926), and sent to the Society, shows a man of remarkable vigor for his years. Even up to very near the end, he retained his clearness of mind, and on April 29th, when the usual monthly check arrived, expressed his great gratitude for the aid which had done so much to make his life comfortable since the summer of 1920.



Gustav Tschermak
Photograph taken about the time of his ninetieth birthday, April 19, 1926

Mineralogists do not need to be informed as to what Tschermak was to Mineralogy and of the work he accomplished. The results of his studies and investigations were numerous and important, especially the outstanding memoirs devoted to the Feldspars (1865), the Micas (1878), the Chlorites (1890), and the Vermiculites (1891). He was also the founder of Tschermak's Mineralogische und Petrographische Mitteilungen and did much to build up the great mineral collection in Vienna. A great leader in Mineralogy has gone, but the record of his life and work will surely arouse the ambition of every worker of today.

When the writer knew him, in the far distant days of 1873–74, he was a fine courtly gentleman in his early manhood, ever kind and helpful to the young American student who had the privilege of a desk in the Vienna Mineral Cabinet.

Madame Tschermak still lives at the age of 89 years, but her mind is clouded so that the loss that has come to her is not realized. We must certainly continue to send money for her support as long as her life goes on. When all is over, it would seem suitable, that Fräulein Lichtblau should receive from the Society a pecuniary expression of what she has done for the family. This plan will be acted upon, when the time arrives, if no objection is expressed.

Edward S. Dana

Errata in April Number of THE AMERICAN MINERALOGIST

Page 110. For numbers in first column, last two lines, for 33 and 89, read 38 and 39.

Plate III, facing 125. Interchange legends and numbers for figures 15 and 16.

Page 131, last column, seventh line from top, for 13 read 3.

Page 176, figure 2. The line between the brachydomes *f* and *x*, and also the letter *f*, are omitted. See figure 4.

Page 182, second line from bottom, for *a* (100), read *c* (100).

Page 184, figure 2, the figure has been tilted 30° to the right and the two letters *r* on the right turned out of position. The line between *c* and *r* should be horizontal.

Pages 185 and 186, figures 5 and 6 are interchanged.

In an address given by Dr. George F. Kunz before the New York Mineralogical Club, the name "Starlite" was suggested for the blue colored zircon that has become so popular recently. The material comes from the vicinity of the old sapphire workings north of Bangkok, Siam, where it occurs at a depth of from five to ten feet in an alluvial deposit. According to Dr. Kunz the blue color is the result of a special heat treatment in which the zircon is brought in contact with fumes liberated from a solution of cobalt nitrate and potassium ferrocyanide.

Professor A. E. Fersman, the well-known Russian mineralogist, was elected Vice-president of the Academy of Sciences of Leningrad, Russia. Dr. Fersman has written numerous books and articles on mineralogical subjects. Recently he prepared a short paper for the readers of our Journal on "Minerals of the Kola Peninsula" which was published in the November (1926) number of THE AMERICAN MINERALOGIST.

Dr. Oliver Bowles, Superintendent of the Bureau of Mines Experiment Station at New Brunswick, New Jersey, gave a short graduate course of lectures at Columbia University on the "Economic Geology of Non-metallic Minerals."

Mr. Lloyd W. Fisher of the Department of Geology, Brown University, has been appointed to the Ella Slack scholarship at Johns Hopkins University. Dr. Hurst of the Dept. of Geology, Ohio State University, has been appointed his successor at Brown.

The Provincial Government of Manitoba has appointed Professor R. C. Wallace, of the Department of Geology and Mineralogy of the University of Manitoba, commissioner of mines.

Mr. Mengo L. Morganthau, well known collector of beautiful and striking mineral specimens, died May 21, 1927, in New York.

BOOK REVIEW

BEITRÄGE ZUR KENNTNIS DER MANGANERZLAGERSTÄTTE VON TSCHIATURI IM KAUKASUS. (Contributions toward the knowledge of the manganese-ore deposit of Tschiaturi in the Caucasus). W. DE LA SAUCE. 90 pages, 7 text figures, 4 sketch-maps and numerous tables. Halle a/S., W. Knapp, 1926.

This pamphlet is essentially a summary report on the geology and petrography of the most important manganese deposit of Europe, one that has played such an important rôle before and during the war as a source of supply for German and British steel industries. It is now largely controlled by the Georgian Manganese Co., Ltd.

The district is located in the new Republic of Georgia, on the Perewissi plateau at an elevation of 700–1000 meters above the level of the Black Sea. The deposits occur in Eocene sediments and cover an area of about 130 sq. kilometers with an estimated supply of over 245 million tons of ore, according to Nikitin.

The ore-bearing strata, 5 to 12 in number, vary in thickness from a few centimeters to 80 centimeters. Interlaminated are layers of sand, sandstone and clay of varying thickness and generally free from lime, so that the total thickness ranges from a few decimeters to about 3.5 meters. These interlaminations are impregnated with the oxides of manganese and iron, so that they exhibit a variety of colors.

The ore itself is considered to be mainly a gel-mineral, *viz.* a polianite-gel (MnO_2); and in contrast with almost all other known manganese deposits, its characteristic structure is dominantly oölitic, although stromatolitic and concretionary structures also occur to a small extent. Chemically it is composed of MnO_2—as high as 91.3%—containing also MnO, Mn_2O_3, Mn_3O_4, and traces of many other elements. According to their physical properties the ores are classified as earthy, soft and hard, or as black ores and red ores.

Mineralogically the ores are composed of the gel-minerals wad, pyrolusite, and psilomelane—varieties of a polianite gel. Braunite (Mn_2O_3) also occurs in small amounts, resembling psilomelane in its physical properties. Finally, manganite ($Mn_2O_3 \cdot H_2O$) is found as the only distinctly crystalline manganese-mineral filling interstices between the oölites.

The deposits are undoubtedly syngenetic sedimentary accumulations, concentrated from manganese-bearing solutions, derived from the surrounding acidic igneous rocks.

Numerous tables are given showing the results of mechanical and chemical analyses, statistics of production and destination of the exports. A summary is also recorded of the historical and political events leading up to the present control of this manganese-producing region by the Harrimans.

M. W. SENSTIUS

NEW MINERAL NAMES

Titanoelpidite

A. LABUNCOV: Titaniferous elpidite from Mount Chibina, Russian Lapland, and its paragenesis. *Compt. Rend. Acad. Sci. I' U. R. S. S.*, (**1926**), 39–42 (In Russian); also A. E. Fersman: *Neues Jahr. Min.*, **55**, 36–46 (1926); also *Am. Mineralogist*, **11**, 289–299 (1926).

NAME: In allusion to its composition: *a titaniferous elpidite*. Given as titaniferous elpidite by Labuncov but as titanoelpidite by Fersman.

CHEMICAL PROPERTIES: An elpidite in which titanium is believed to exceed the zirconium. $H_2O=9.1$.

CRYSTALLOGRAPHIC PROPERTIES: Orthorhombic, in crystals elongated parallel to *b*. Forms: (110), (100), (010), (120), (111), (011), (102), (001). *m*:*m* 54°6′.

PHYSICAL AND OPTICAL PROPERTIES: Color brown or rose yellow, pleochroic. X=colorless; Y=yellow; streak light brown or rose yellow. Biaxial, positive. $\alpha=1.681$, $\beta=1.686$, $\gamma=1.698$; birefringence 0.017. $Z=a$, $Y=c$, $X=b$. Dispersion $\rho>v$.

OCCURRENCE: Associated with albite and manganese oxide in the contact area of the nephelite syenites at Mount Chibina, Russian Lapland.

W. F. FOSHAG

Schultenite

L. J. SPENCER: Schultenite, a new mineral from Southwest Africa. *Mineral. Mag.*, **21**, No. 115, pp. 149–155 (1926).

NAME: In honor of Baron A. de *Schulten*, who prepared this mineral synthetically.

CHEMICAL PROPERTIES: A hydrous arsenate of lead. Formula, $2PbO\cdot As_2O_5\cdot H_2O$. Analysis: PbO 63.97, As_2O_5 32.18, H_2O 2.88. Sum 99.03.

CRYSTALLOGRAPHIC PROPERTIES: Monoclinic, holohedral. $a:b:c=0.8643:1:0.7181$. $\beta=84°36'$. Habit, thin plates tabular to *b* (010), sixteen forms noted of which the most prominent ones are *p* (111), *l* (130), *b* (010), *c* (001). Cleavage *b* (010) good.

PHYSICAL AND OPTICAL PROPERTIES: Colorless, luster brilliant vitreous to adamantine. Biaxial positive. 2E=136°38′. 2V=58°14′. Plane of the optic axes normal to the plane of symmetry and lying in the obtuse angle β; $X=b$, $Y\wedge c=24°$, $Z\wedge c=66°$. $\alpha=1.8903$ (calculated), $\beta=1.9097$, $\gamma=1.9765$. H=2.5. Sp. Gr. 5.943.

OCCURRENCE: Found on a specimen from Tsumeb, Otavi, Southwest Africa, on a matrix of bayldonite pseudomorphous after anglesite, azurite and mimetite.

W. F. F.